

II. Nakhla

Clinopyroxenite, 10 kg.
shower, seen to fall



Figure II-1. Three largest pieces of Nakhla meteorite (1813 grams, 1651 grams and 1318 grams). Photo courtesy of Gaber M. Naim, Director, Egyptian Geological Survey.

Introduction

Multiple fragments of the Nakhla meteorite were seen to fall as a shower in the hamlets surrounding the village of El-Nakhla, El-Baharîya in Egypt (near Alexandria) on June 28th, 1911 at 9:00 a.m. Dr. W. F. Hume, Director of the Geological Survey of Egypt, personally visited the site and collected both the evidence of eye-witnesses of the fall and about a dozen specimens including the largest known fragments (Hume, 1911; Ball, 1912) (figure II-1).

The following account is from Attia *et al.* (1955). *"From the evidence of eye-witnesses, it appears that the stones fell over an area of 4.5 kilometers in diameter; and were derived from the explosion of a single meteorite. The explosion seems to be repeated several times and the track of the meteorite was marked by a column of white smoke. The stones buried themselves in the ground to depths ranging from 10-30 cm and the holes caused showed some inclination. Altogether about forty stones, of a total weight of nearly 10 kilograms, were collected. Of these, about half are completely enveloped in a black varnish-like skin of fused matter. Some have one or more of their faces only partially fused,*

while others exhibit fresh fractures showing greenish-gray crystalline interior. The weights of the individual stones range from 1813 grams in the largest specimen down to about 20 grams in the smallest. The smallest fragment of which the fused skin is entire weighs 34 grams."

The exact strewn field for the Nakhla shower is unmapped, but is said to be within a diameter of 4.5 km (Prior, 1912). It is not known how many additional samples have been found in later years.

Petrography

Nakhla is an olivine-bearing clinopyroxenite consisting mostly of augite with less abundant Fe-rich olivine, plagioclase, K-feldspars, Fe-Ti oxides, FeS, pyrite, chalcopyrite and a hydrated alteration phase that resembles iddingsite (Prior, 1912; Bunch and Reid, 1975; Reid and Bunch, 1975; Weinke, 1978; Harvey and McSween, 1992 b,d; Treiman, 1986, 1990, 1993 a,d).

In Nakhla, euhedral and subhedral sub-calcic augite grains (0.5 to 1.0 mm) are set in a fine-grained

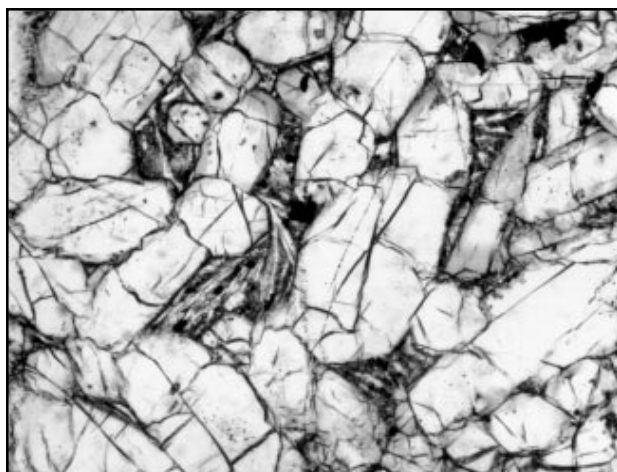


Figure II-2. Photomicrograph of thin section of Nakhla meteorite illustrating close-packed, elongate clinopyroxene crystals and minor mesostasis with lath-like plagioclase. Field of view is 2.2 mm.

mesostasis of thin radiating laths of plagioclase, pyroxenes, olivine, magnetite and other minerals (figure II-2). Minor subhedral olivine grains up to 2-4 mm are also present (Treiman, 1990). Nakamura *et al.* (1982a) observed poikilitic intergrowths between olivines and pyroxenes indicating substantial adcumulus growth. The mineral mode is approximately 10% olivine, 80% augite and 10% mesostasis, but Friedman *et al.* (1994) found that the ratio of pyroxene:olivine varied from 4:1 to over 17:1 in 8 different samples of Nakhla.

The nakhlites (Nakhla, Lafayette and Governador Valadares) have been interpreted as cumulates (*i.e.* Bunch and Reid, 1975; Gale *et al.*, 1975). However, Treiman (1987) and Treiman *et al.* (1996) found a close comparison of Nakhla with “Theo’s flow,” which is an extrusive Archean flow in Canada. Prior (1912) noted that the interstitial mesostasis was “*like the matrix of a fine-grained basalt*”. The elongate pyroxenes in the nakhlites are weakly aligned (Berkley *et al.*, 1980). The nakhlite meteorites have experienced varying degrees of late-magmatic and sub-solidus diffusive re-equilibration (Harvey and McSween, 1992).

The olivine grains in Nakhla are contain occasional magmatic inclusions (figure II-3). The inclusions have mostly re-crystallized, but it has proven possible to use them to calculate the composition of the initial melt (Treiman, 1986, 1993; Harvey and McSween, 1992d).

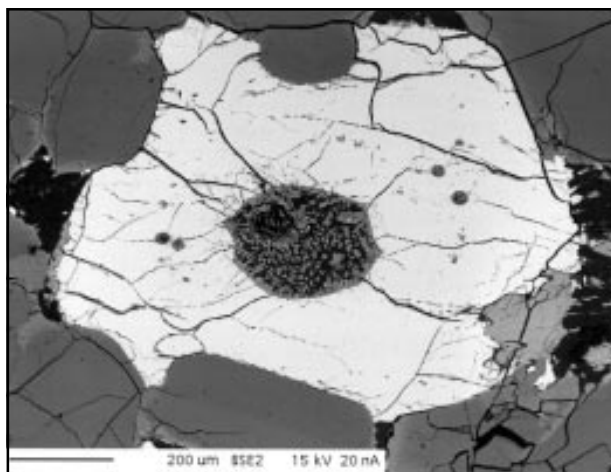


Figure II-3. Backscattered electron image of large recrystallized “melt” inclusion in olivine (bright) in Nakhla (note the vesicle in the melt inclusion). Olivine is surrounded by close-packed clinopyroxene crystals. Field of view is 1.2 mm. Image taken by Vincent Yang after figure 1 in Treiman (1993), GCA 57, 4756.

Delano and Arculus (1980) experimentally determined that Nakhla crystallized at a higher oxygen fugacity than basaltic achondrites. Re/Os fractionation also indicates that the source of Nakhla magma was oxidized (Birck and Allègre, 1994). The sample contains oxidized iron in the magnetite.

Nakhla has been only mildly shocked with an estimated peak pressure of about 20 Gpa (Greshake, 1998).

Aqueous alteration of nakhlites may have occurred on Mars (Gooding *et al.* 1991) (*see sections on “Salts” and “Radiogenic Isotopes”.*) Musselwhite *et al.* (1991) presented a model where radioactive ^{129}I was introduced during this weathering, but Gilmour *et al.* (1997) have disproved this model by showing that the Xe isotope anomalies are found in all the minerals.

Mineral Chemistry

Olivine: The olivine in nakhlites has higher Fe/Mg (Fa_{65-75}) than that of coexisting pyroxene (Fs_{30-40}). The olivine in Nakhla is zoned in composition with steep Mg/Fe profiles in the core regions and progressively flatter toward the crystal boundaries (Harvey and McSween, 1991). The Ca content of olivine is also zoned, first from low Ca to high, then a decrease believed to correspond with onset of augite crystallization. Nakamura *et al.* (1982) reported REE abundance in olivine, but this may include the REE in magmatic inclusions and attached mesostasis (figure

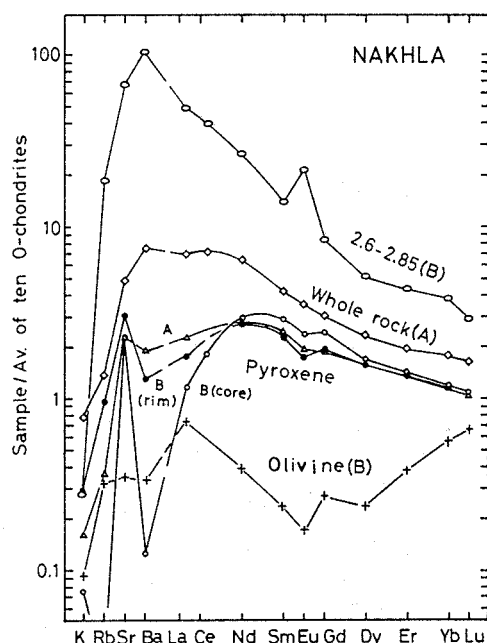


Figure II-4. Chondrite normalized REE and other LIL element abundance patterns for whole rock and mineral separates of Nakhla. This is a copy of figure 2 in Nakamura *et al.* (1982), *GCA* **46**, 1559.

II-4). Wadhwa and Crozaz (1995) determined REE by ion probe. Smith *et al.* (1983) reported relatively high Ni and Ca contents in olivines and showed that they were not of “plutonic” origin.

Clinopyroxene: The major mineral is augite ($Wo_{40}En_{40}Fs_{20}$). Bunch and Reid (1975), Treiman (1990) and Harvey and McSween (1991) found that the cores of the clinopyroxenes in Nakhla were homogeneous with zoning towards Fe enrichment at the rims, with steep transition zones in between (figure II-5). Allen and Mason (1973), Nakamura *et al.* (1982) and Wadhwa and Crozaz (1995a) reported the REE abundances in pyroxene from Nakhla. Smith *et al.* (1983) carefully determined the minor element content (Mn, Ti, Al, Cr, Na) of pyroxene in Nakhla. Some grains of clinopyroxene show polysynthetic twinning which may have been caused by shock. Greshake (1998) has carefully studied the exsolution in augite in Nakhla. Mikouchi and Miyamoto (1997) have carefully compared the pyroxenes found in the nakhlites.

Plagioclase: Bunch and Reid (1975) gave the composition of plagioclase as $Or_4Ab_{62}An_{34}$. In Nakhla, plagioclase is birefringent and apparently was not maskelynitized by shock (Greshake, 1998).

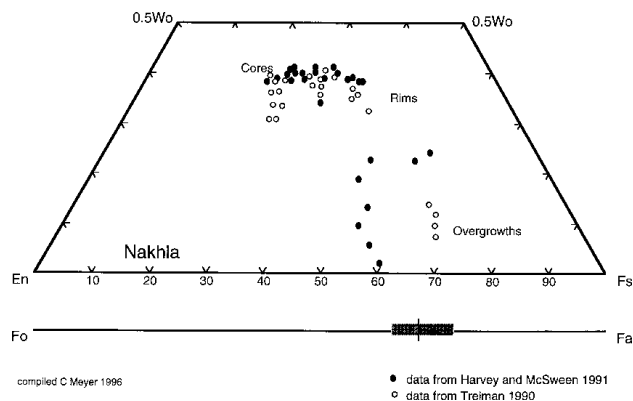


Figure II-5. Pyroxene and olivine composition diagram. Data replotted from Harvey and McSween (1991) and Treiman (1990). Note that olivine phenocrysts have composition in equilibrium with final melt, rather than with the first-formed pyroxene.

K-feldspar: Bunch and Reid (1975) reported that potassium feldspar ($Or_{74}Ab_{24}An_{2.4}$) occurs in the mesostasis.

Cl-apatite: Crozaz (1979) studied the U and Th distribution in Nakhla and determined the Th/U ratio in small grains (30 microns) of Cl-apatite. Bridges and Grady (1997) reported chlorapatite.

Iddingsite: Reid and Bunch (1975) noted the fibrous habit of the alteration in Nakhla and concluded that it was “pre-terrestrial”. Ashworth and Hutchison (1975) studied the iddingsite with high-voltage electron microscopy and argued that it was of extra-terrestrial origin, because it was remobilized by the shock event. Gooding *et al.* (1991) tentatively identified smectite in this “iddingsite.” (see also Lafayette) Papanastassiou and Wasserburg (1974) reported high K (~7 wt. %) in brown “films” in pyroxene.

Glass: Interstitial glass has been analyzed by Berkley *et al.* (1980). Gale *et al.* (1975) also reported glass in Nakhla as one of their “mineral” separates.

Magnetite: Ti-rich magnetite with ilmenite exsolution is an important phase in Nakhla (Bunch and Reid, 1975, Ashworth and Hutchison, 1975). Magnetite is also one of the “mineral” separates analyzed by Gale *et al.* (1975). Weinke (1978) found that the magnetite contained substantial Fe^{+3} .

Symplectite: Mikouchi and Miyamoto (1997) have found thin lamellar symplectic inclusions composed of augite and magnetite in host olivine.

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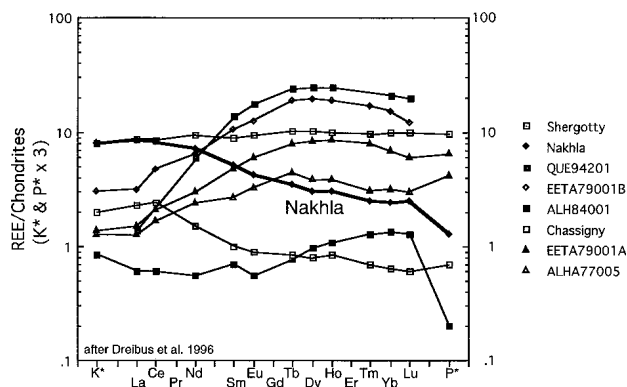


Figure II-6. Chondrite normalized REE abundance patterns for whole rock. Diagram replotted from Dreibus *et al.* (1996).

Ilmenite: Harvey and McSween (1992d) determined the composition of ilmenite in a magmatic inclusion in Nakhla olivine.

Sulfides: Bunch and Reid (1975) observed that the sulfide grains ranged from “fresh to altered grains that had a weathered appearance”. They tentatively reported both “stoichiometric” pyrite and FeS (pyrrhotite ?) with 0.2 to 0.5% Ni. Weinke (1978) gave a complete analysis of “troilite”. Greenwood *et al.* (1998) report minor chalcopyrite associated with pyrrhotite and have determined the isotopic composition of S.

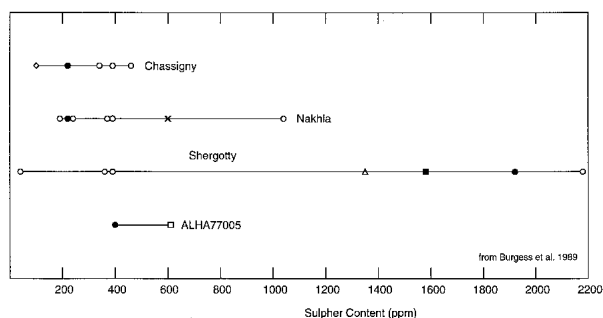


Figure II-7. Total sulfur contents determined for SNC meteorites. This is figure 2 in Burgess *et al.* (1989), *EPSL* 93, 316.

Salts: Wentworth and Gooding (1988a,b, 1989) and Gooding *et al.* (1991) have reported minor, but important, amounts of Ca-carbonate, Ca-sulfate, Mg-sulfate, NaCl, and “rust” including a clay mineral tentatively identified as smectite (*see discussion in “Other Isotopes”*). Bridges and Grady (1997) found large grains of halite (400 microns) with included grains of plagioclase, silica, chlorapatite, siderite and anhydrite and have argued that this halite is igneous in origin and formed from the magma! Bridges and Grady (1998a,b) also reported analyses of siderite.

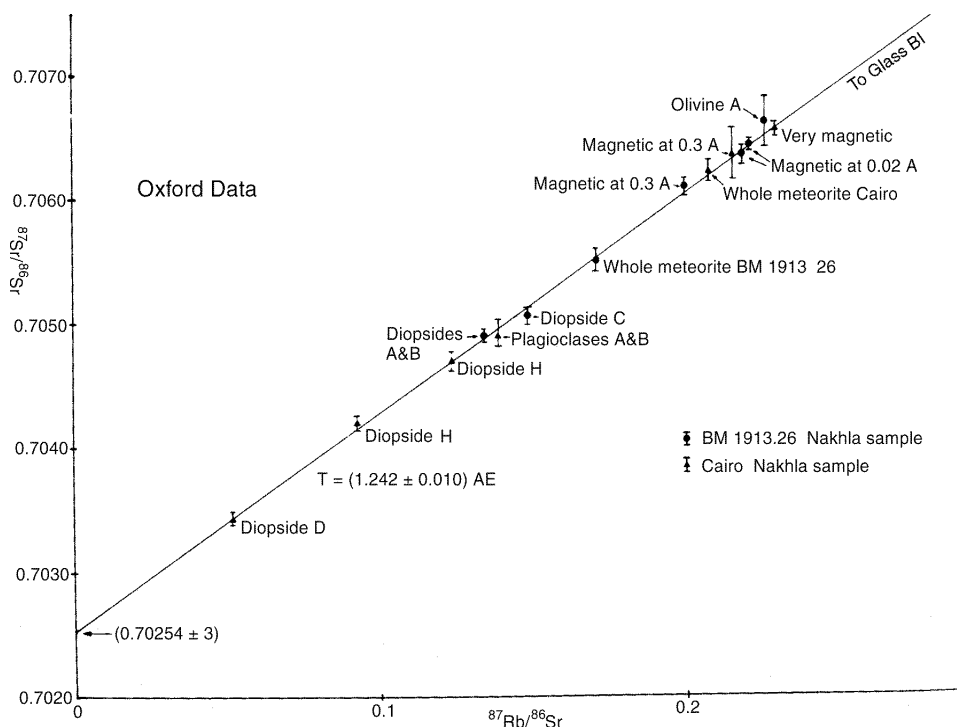


Figure II-8. Rb-Sr isochron for Nakhla determined by Gale *et al.* (1975). This is figure 2 in their paper in *EPSL* 26, 200.

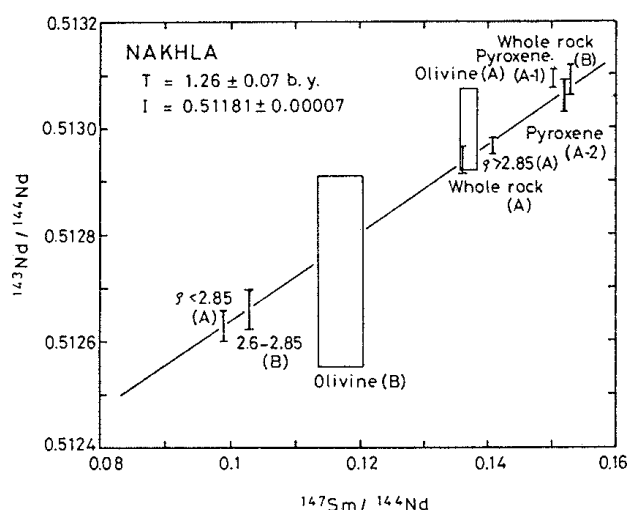


Figure II-9. Sm-Nd isochron for Nakhla determined by Nakamura *et al.* (1982). This is figure 1 in their paper in *GCA* **46**, 1558.

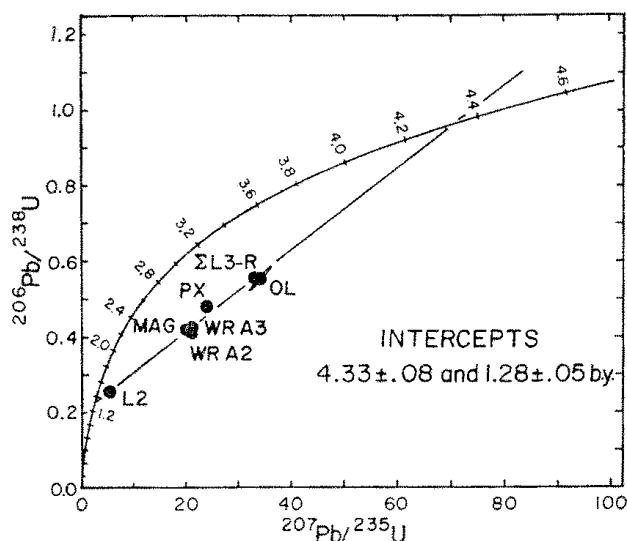


Figure II-10. U-Pb concordia diagram for mineral separates from Nakhla. This is figure 4 in paper by Nakamura *et al.* (1982), *GCA* **46**, 1563.

Whole-rock Composition

Major element analyses were reported by Prior (1912), McCarthy *et al.* (1974), and Dreibus *et al.* (1982) (Table II-1). Schmitt and Smith (1963) first reported REE analyses of Nakhla and Lafayette and recognized that they had REE patterns similar to terrestrial basalts (*i.e.* Kilauea)! Weinke (1978) gave a trace element analysis of Nakhla. The REE analysis by Nakamura *et al.* (1982) is plotted in figure II-4 and Dreibus *et al.* (1982) in figure II-6. Laul *et al.* (1971) found that Nakhla had volatile element abundances similar to those in ocean ridge basalts. Treiman (1987), Treiman *et al.* (1996) and Friedman *et al.* (1997) found a close

comparison of texture and mineralogy Nakhla with Theo's flow, which is an extrusive Archean flow in Canada.

In addition to the data in table II-1, Clark *et al.* (1967) determined 40 ppb U. Curtis *et al.* (1980) determined two values for B (4.6 and 255 ppm) for the Nakhla meteorite. Gibson and Moore (1983) determined 1040 ppm S for one piece and Gibson *et al.* (1985) determined values of 260, 200, 330 and 360 ppm S for additional pieces. Burgess *et al.* (1989) determined 220 ppm S and found that it was released over a wide range of temperatures (figure II-7). Mermelengas *et al.* (1979) determined 23 ppb Pd. Smith *et al.* (1977) determined 90 ppb Te. Ehmann and Lovering (1967) determined 0.22 to 0.25 ppm Hg, but this is probably laboratory contamination, as Weinke (1978) determined only 0.7 ppb Hg. Wang *et al.* (1997) reported a wide range of volatile trace elements (figure II-13) with no apparent difference between Antarctic and non-Antarctic Martian meteorites.

The nakhlites contain a minor amount of H₂O as hydrous silicate minerals (Ashworth and Hutchison, 1975; Bunch and Reid, 1975; Gooding *et al.*, 1991; Treiman *et al.*, 1993). These altered areas are probably the same as the "brownies" observed by Papanastassiou and Wasserburg (1974). Karlsson *et al.* (1992) reported 0.114 wt % H₂O for Nakhla. Watson *et al.* (1994) also reported 0.11 % H₂O. Gooding *et al.* (1990) determined the thermal release pattern for several volatile species.

Papanastassiou and Wasserburg (1974) noted that the Rb/Sr and K/U of the parent planet for Nakhla were similar to the composition of the Earth.

Radiogenic Isotopes

Stauffer (1962) originally reported a K-Ar age of 1.3 Ga for Nakhla. Using ⁴He and ⁴⁰Ar, Ganapathy and Anders (1969) calculated "gas retention ages" of 0.77 Ga and 1.4 ± 0.3 Ga respectively for Nakhla. Podeseck (1973) reported an ⁴⁰Ar/³⁹Ar age of ~ 1.3 Ga. Using Rb-Sr ($\lambda_{\text{Rb}} = 1.39 \times 10^{-11} \text{ year}^{-1}$), Papanastassiou and Wasserburg (1974) determined an age of about 1.31-1.37 Ga and Gale *et al.* (1975) 1.24 ± 0.01 Ga (figure II-8). K-Ar ages are also reported for different separates by Gilmour *et al.* (1997).

Nakamura *et al.* (1977, 1982) used the Sm-Nd system to determine an age of 1.26 ± 0.07 Ga (figure II-9). Hutchison *et al.* (1975), Nakamura *et al.* (1982) and

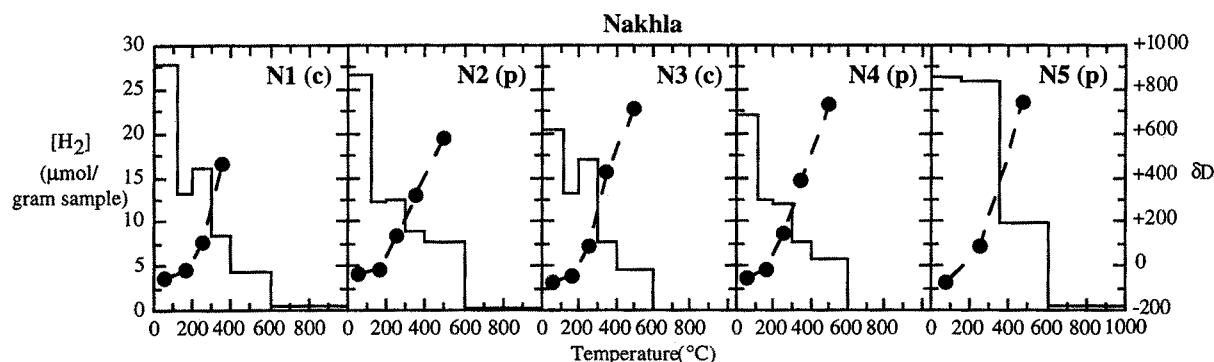


Figure II-11. Hydrogen isotopic composition of water released from the Nakhla meteorite during pyrolysis (p) and combustion (c) experiments by Leshin *et al.* (1996c). This is figure 1 in their paper in *GCA* **60**, 2635.

Chen and Wasserburg (1986b) tried to determine a U-Pb age (figure II-10) — without agreement.

Gooding *et al.* (1991) discuss the effect that pre-terrestrial aqueous alteration (weathering) might have had on the disturbance of the Rb-Sr system. K-Ar ages of iddingsite were reported by Swindle *et al.* (1997) (see also discussion in Lafayette).

Cosmogenic Isotopes and Exposure Ages

Using ^3He , ^{21}Ne and ^{38}Ar , Ganapathy and Anders (1969) calculated an average cosmic-ray exposure age of 10.1 Ma for Nakhla (see figure I-11). Using new production rates, Bogard (1995) calculated 12 Ma from the ^{21}Ne data and 11 Ma from the ^3He data. Measured ^{14}C activity of about 53.3 ± 0.4 dpm/kg. (Jull *et al.* 1997) is consistent with saturation (61 ± 9 dpm/kg.).

Nakhla has been on Earth for 85 years.

Other Isotopes

Taylor *et al.* (1965) found that the ratio of oxygen isotopes $^{18}\text{O}/^{16}\text{O}$ in pyroxenes from Nakhla were similar to those in Shergotty and different from those in howardites and eucrites. Clayton and Mayeda (1983, 1996) reported the oxygen isotopes for Nakhla. Clayton (1993) reported the $^{18}\text{O}/^{16}\text{O}$ composition of olivine and pyroxene from Nakhla. Karlsson *et al.* (1992) found that the oxygen isotopes in water released from Nakhla and other Martian meteorites was enriched in ^{17}O , suggesting that the past hydrosphere on Mars was from a different reservoir than the lithosphere. Baker *et al.* (1998) have determined the isotopic composition of oxygen in water released during heating of Nakhla. Saxton *et al.* (1997,

1998) reported $\delta^{18}\text{O} = 34 \pm 1$ ‰ for 4 grains of siderite - which makes it the heaviest Martian carbonate!!

Fallick *et al.* (1983), Kerridge (1988), Watson *et al.* (1994) and Leshin *et al.* (1996) have reported on the hydrogen isotopic composition of water released from Nakhla (figure II-11). The hydrogen released at high temperatures is rich in deuterium, but the hydrogen released at low temperature has a terrestrial ratio.

Molini-Velsko *et al.* (1986) found that the isotopic composition of Si was normal.

Ott and Begemann (1985) showed that there was excess ^{129}Xe in Nakhla. Musselwhite *et al.* (1991), Drake *et al.* (1993, 1994) and Swindle (1995) have discussed the origin of this excess and argued for an ancient Martian alteration effect. Turner *et al.* (1996) have reported excess ^{129}Xe within Nakhla pyroxene. Ott *et al.* (1988) found that Xe in carefully etched “residue” from Nakhla was like that of Chassigny. Gilmour *et al.* (1997, 1998) have continued these studies on mineral separates in order to determine the exact siting of the Xe in Nakhla.

Fallick *et al.* (1983) and Carr *et al.* (1985) have reported on the isotopic composition of carbon. Carr *et al.* argued that the heavy carbon ($\delta^{13}\text{C} = +12$ to $+24$ ‰) may be from carbonates that are produced by weathering on Mars. The carbon and nitrogen content and isotopic composition has also been reported by Wright *et al.* (1992). Using leaching experiments to get rid of ^{14}C component, Jull *et al.* (1995) found that the $\delta^{13}\text{C}$ for carbon in Nakhla was as heavy as $+35$ ‰. Grady *et al.* 1995b reconsidered the data of Carr *et al.* for ^{13}C after acid dissolution

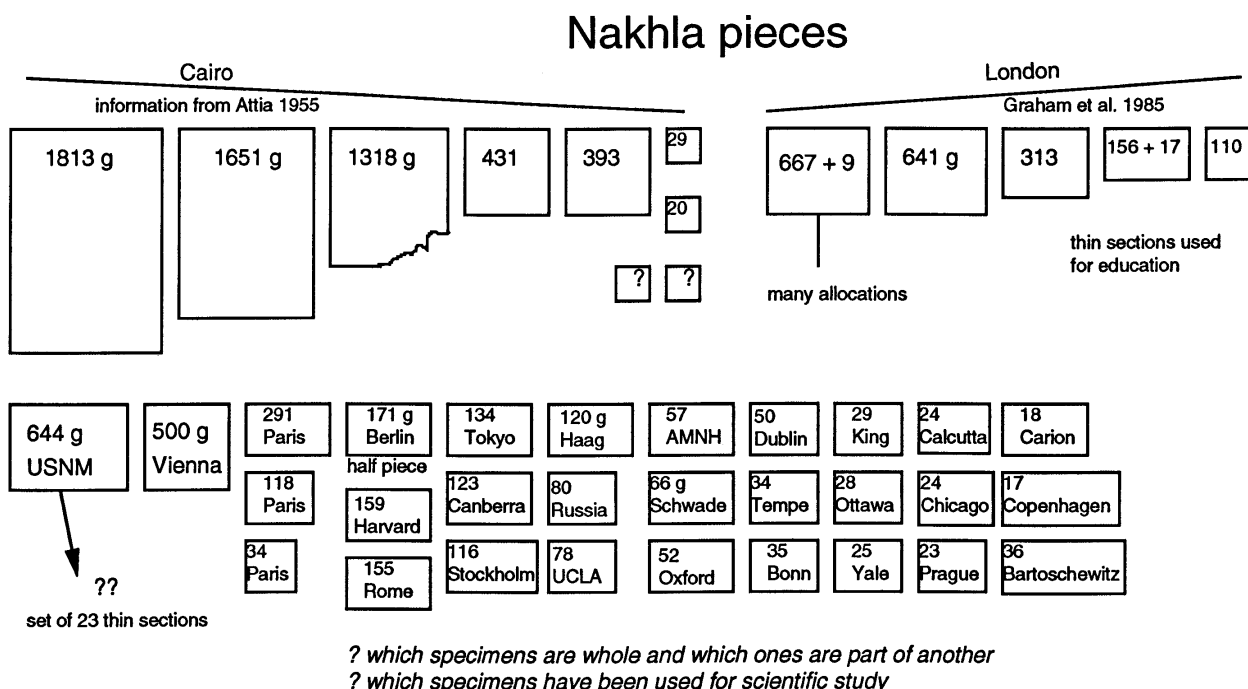


Figure II-12. Schematic drawing showing location of pieces of the Nakhla meteorite today. It is not known which samples have been used for research, or if all fragments are alike. Please forward information to the author.

experiments and concluded that very heavy carbon ($\delta^{13}\text{C} = +50\text{‰}$) of Martian origin was present. This value is similar to the isotopic ratio of carbon in the carbonate in ALH84001, and seems to verify the conclusions by Reid and Bunch (1975), Carr *et al.* (1985) and Gooding *et al.* (1991), that the weathering in Nakhla occurred on Mars, not during the time it has been on Earth. Wright *et al.* (1997) have begun a detailed study of the isotopic composition of carbon in PAHs, hydrocarbons and organics found in Nakhla for comparison with same compounds found in Martian meteorites from Antarctica.

Harper *et al.* (1995) reported a small but significant excess of ^{142}Nd in Nakhla. According to Harper *et al.*, “This anomaly records differentiation in the Martian mantle before 4539 million years ago and implies that Mars experienced no giant impacts at any time later than 27 million years after the origin of the solar system.” This isotopic anomaly has now also been observed in Chassigny by Jagoutz (1996). Lee and Halliday (1997) also reported excess ^{182}W in Nakhla.

Birck and Allègre (1994) have studied the Re-Os isotopic systematics of Nakhla. The Os isotopic

composition was found to be radiogenic. From the Re/Os fractionation they conclude the mantle of Mars has a relatively high oxidation state. Note that Smith *et al.* (1983) showed that the relatively high Ni content of olivine and pyroxene in nakhlites also indicated relatively oxidizing conditions.

Hutchison *et al.* (1975), Nakamura *et al.* (1982), and Chen and Wasserburg (1986b) have studied the U-Th-Pb isotopic system for Nakhla. Chen and Wasserburg discussed the problem of “terrestrial Pb” contamination. In fact, one must now also consider contamination by “Martian Pb” during the alteration process that has been shown to have occurred on Mars (Gooding, 1991).

Miscellaneous Studies

Bhandari *et al.* (1971) reported track evidence for superheavy elements in diopside from Nakhla and this led to a rash of studies (Carver and Anders, 1976; Green *et al.*, 1978; Crozaz, 1979). It turned out that the long etched tracks in Nakhla observed by Bhandari are a shock-related feature and not due to the presence of extinct “superheavy” elements (*i. e.* Nakhla is too young to have incorporated short-lived superheavy elements).

Kaneda *et al.* (1997) and McKay *et al.* (1993, 1994) have performed experiments to determine trace element partitioning between pyroxene and synthetic melts.

Hamilton *et al.* (1997) obtained spectra of Nakhla (see figure VIII-13).

Processing

Although Nakhla is considered as one meteorite, it arrived as a shower of many pieces (~40), most apparently with fusion crusts (*see Introduction*). It is not known from which pieces the main research has been done, or if all pieces are the same. Note that Friedman *et al.* (1994) have been looking at thin sections of different portions of Nakhla to see what variability may exist.

Nakhla has been widely distributed (table I-3, figure II-12). In 1955, the Cairo museum had individual specimens weighing 1813 g, 1651 g, 1318 g, 431 g, 393 g, 29 g and 20 g (Attia *et al.*, 1955). In 1985, Graham *et al.* list specimens as follows (British Museum 667+9 g, 641 g, 313 g, 156+14 g and 110 g; Smithsonian 644 g; Berlin 602 g; Vienna 500 g; Paris 430 g; Harvard 159 g). Additional samples that are known include 123 grams at the Research School of Earth Science in Canberra, 80 grams in Russia, 78 grams at UCLA, 50 grams in Dublin, 28 grams in Ottawa, 34 grams in Tempe and 23 grams in Prague. Note that this totals to only about 10 kg., but according to Graham *et al.* (1985), the weight was thought to be 40 kg. The reason for this discrepancy is not known, but it seems clear that the actual weight collected was only about 10 kg. (Attia *et al.*, 1955).

Thin sections of the Nakhla meteorite are included in the educational thin section sets distributed by the Museum of Natural History (Grady and Hutchison, 1996). One set of 23 consecutive thin sections is available from the Smithsonian.

Currently, there is an initiative to carefully study a large piece of Nakhla, using the most modern tools available (contact Monica Grady).

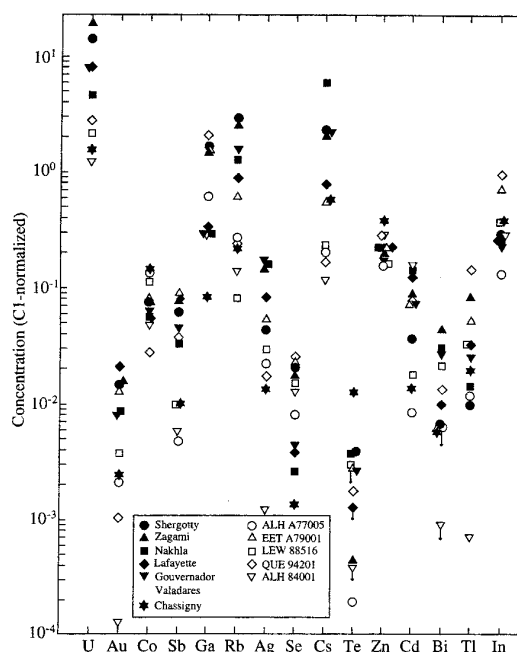


Figure II-13. Trace elements in Martian meteorites determined by Wang *et al.* (1997) as presented in LPSC XXVIII, 1494. Filled symbols are for samples found on the ice in Antarctica.

	$^{129}\text{Xe}/^{132}\text{Xe}$	^{132}Xe [$10^{-12}\text{cm}^3/\text{g}$]	I [ppb]	Br [ppb]	Cl [ppm]	La [ppm]	Br/I	Br/La ($\times 10^{-3}$)
Mars								
Atmosphere:	2.5 ⁶	0.75 ⁶						
Basalts:								
Shergotty	1.19 ¹¹ ; 1.36 ¹¹ 1.34 ¹²	9.21 ¹¹ ; 5.56 ¹¹ 4.03 ¹²	36	890	108	2.44	25	400
Zagami	1.51 ¹³ 1.50 ¹⁴	9.6 ¹³ 4.13 ¹⁴	15 5.2	640 670	130 133	2.02 2.98	43 130	320 225
EETA79001A	0.977 ¹⁵	3.66 ¹⁵	<100*	189	26	0.37	----	510
EETA79001B			960*	287	48	0.80	----	360
EETA79001C-glass (trap. atmosphere)	2.422 ¹² ; 2.231 ¹⁵	37.4 ¹² ; 24.6 ¹⁵	<12	378	35	0.30	>31	1180
QUE 94201			4600*	350	91	0.35	----	1000
Lherzolites:								
ALHA77005	1.11 ¹²	6.02 ¹²	1720*	69	14	0.32	----	220
LEW 88516	1.284 ¹⁶	15.2 ¹⁶	60	50	29	0.27	----	190
Cumulates:								
Lafayette	1.26 ¹³ ; 1.29 ¹³	18.7 ¹³ ; 8.8 ¹³	54	590	101	2.0	11	295
Nakhla	1.56 ¹¹ ; 1.38 ¹¹ 1.90 ¹³ ; 1.18 ¹³	3.01 ¹¹ ; 3.78 ¹¹ 5.7 ¹³ ; 2.8 ¹³	17 24	3460** 3410**	1890** 563**	2.18	200 140	1590
ALH84001	1.83 ⁷ ; 1.97 ⁷	6.7 ⁷ ; 24.6 ⁷	17	65	12	0.14	3.8	464
Chassigny	1.029 ¹¹	22.9 ¹¹	<10	97	34	0.59	>10	165
Earth								
Atmosphere	0.98 ⁶	15.6 ⁶						
Basalts - MORB								
CH98 DR10			12	159	71	2.7	13	59
CH98 DR11	1.002 ¹⁷	1.37 ¹⁷	11	90	28	2.7	8	33
CH98 DR12	1.015 ¹⁷	0.57 ¹⁷	<6	64	22	2.8	>11	23
CH98 DR15			8	62	43	2.3	7	27
CH98 DR17			5	196	89	2.8	38	70
OIB								
1699	0.988 ¹⁷	1.16 ¹⁷	20	344	177	10	17	34
1701	0.989 ¹⁷	1.68 ¹⁷	27	310	233	10	11	31
1712	0.989 ¹⁷	0.64 ¹⁷	61	550	200	9.7	9	57
Spinel-lherzolite			4.2	12	1.4	0.36	3	33
CI (Orgueil)	1.07 ¹⁸	8.13 ¹⁸	560	2530	678	0.245	4.5	10326

* Meteorites from Antarctica are generally heavily contaminated with iodine [19]. Hence, these iodine data and the one for Lafayette (a find) have to be considered as upper limits only.

** terrestrial contamination ?

Figure II-14. Summary of halogens found in Martian meteorites as reported by Dreibus et al. (1997).

